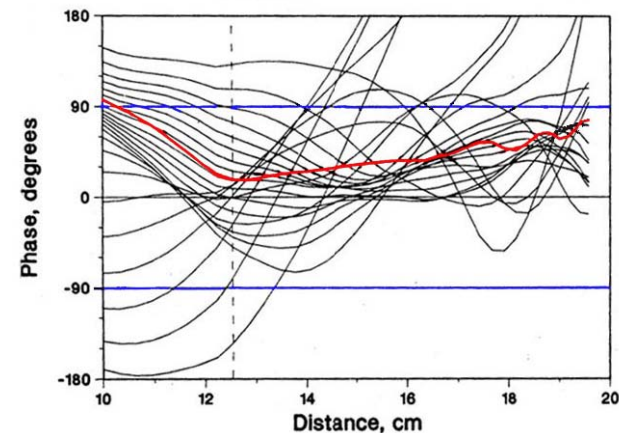


Traveling-Wave Tube Efficiency Enhancement

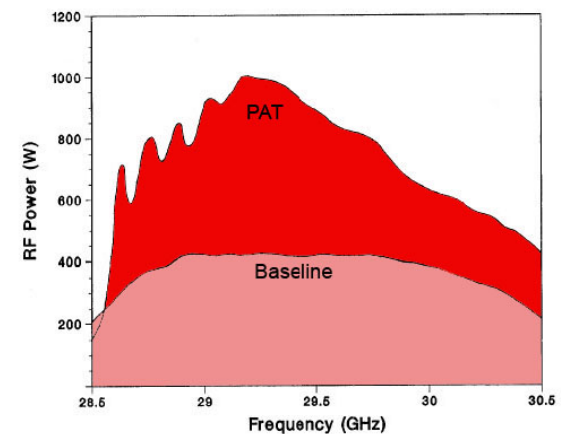
Traveling-wave tubes (TWT's) are used to amplify microwave communication signals on virtually all NASA and commercial spacecraft. Because TWT's are a primary power user, increasing their power efficiency is important for reducing spacecraft weight and cost. NASA Glenn Research Center has played a major role in increasing TWT efficiency over the last thirty years. In particular, two types of efficiency optimization algorithms have been developed for coupled-cavity TWT's. The first is the phase-adjusted taper which was used to increase the RF power from 420 to 1000 watts and the RF efficiency from 9.6% to 22.6% for a Ka-band (29.5 GHz) TWT. This was a record efficiency at this frequency level. The second is an optimization algorithm based on simulated annealing. This improved algorithm is more general and can be used to optimize efficiency over a frequency bandwidth and to provide a robust design for very high frequency TWT's in which dimensional tolerance variations are significant.

Phase-Adjusted Taper

- Algorithm developed by J. Wilson to optimize coupled-cavity TWT efficiency .
- Programmed into NASA 2-D Coupled-Cavity TWT Code.
- Adjusted phase of electron bunch with respect to RF wave:
 - Strong bunch formation at beginning
 - Strong power transfer at end
- Utilized in experimental Ka-band ferruleless CC TWT for NASA/ Hughes EDD low distortion program.
- Increased peak RF power from 420 W to 1000 W and RF efficiency from 9.6% to 22.6%.
- Record Ka-band RF efficiency achieved with low gain per cavity slow-wave circuit.



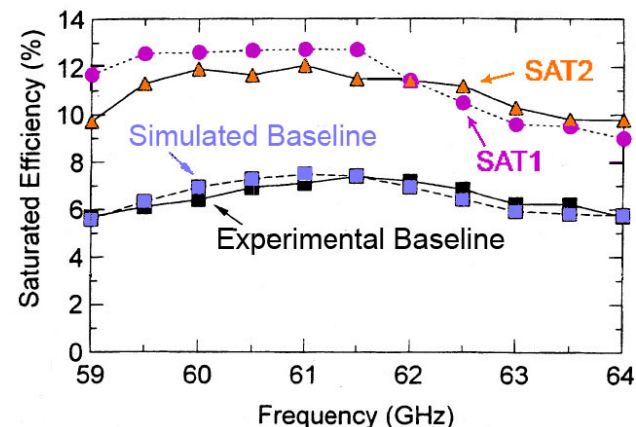
Bunch phase represented by red line provides strong bunch formation at beginning and power transfer at end.



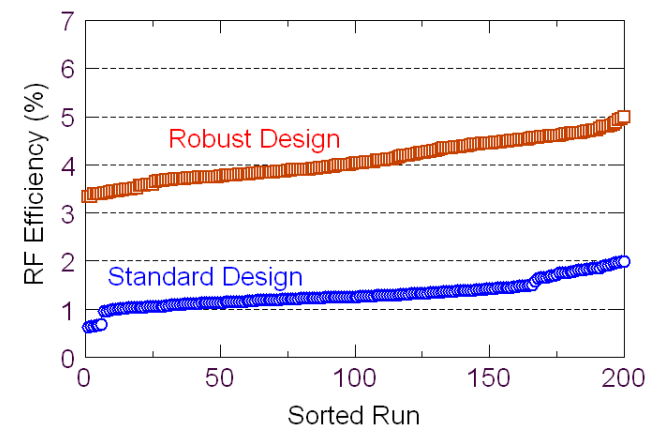
Experimental RF power of Ka-band ferruleless TWTs.

Simulated Annealing Tapers

- An improved and more generalized approach to taper design using simulated annealing was developed by J. Wilson.
- Concept based on metal annealing.
- Simulated annealing escapes from local optima and enables global optimum solution to be obtained.
- Versions developed for optimizing the minimum efficiency over a specified bandwidth:
 - SAT1 optimizes instantaneous BW at single input power value
 - SAT2 allows input power to provide saturation at each frequency
- A robust version developed to take into account dimensional tolerance variations – especially useful at high frequencies.



Calculated results of bandwidth optimizations SAT1 and SAT2 for V-band TWT.



Calculated results for 200 runs with randomized variations in high frequency folded-waveguide TWT for robust and standard SATs.